**Housing system may affect behavior and performance of Jersey heifer calves.** *By Pempek et al.* The literature to date with regard to alternative management systems for dairy calves is breed-specific; nearly all studies have been conducted with Holstein calves. It is currently unknown if co-housing promotes the welfare of Jersey calves. In this experiment, pre-weaned Jersey heifer calves were housed individually or in pairs; growth and behavior were recorded. Pair-housed heifers had better measures of growth performance, but demonstrated more undesirable social behaviors compared to individually housed calves.



# Housing System May Affect Behavior and Performance of Jersey Heifer Calves.

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**ABSTRACT**

There is increasing social pressure to adopt alternative housing and management practices that allow farm animals more opportunity to exercise and demonstrate social behavior. The present study investigated the effect of paired housing on the behavior and performance of Jersey heifer calves. Forty female Jersey calves were allocated to individual or pair housing at birth and monitored for 9 wk. Calves were provided with a single hutch, and those allocated to the paired housing treatment were provided a pen enclosure twice the size of individually housed calves and only one hutch was provided per pair. All calves were fed milk replacer via bucket twice per day (1.9 L/feeding first 7 d; 2.27 L/feeding until weaned) and had ad libitum access to calf starter and water. Gradual weaning commenced on day 49 by reducing the calves' milk allowance to one feeding per day and weaning occurred on day 56. Grain consumption was monitored daily and calves were weighed weekly. Direct behavioral observations were conducted twice per week. Calves housed in pairs tended to have greater average daily gain (ADG) compared with calves housed individually (0.63 ± 0.02 versus 0.59 ± 0.02 kg/d; respectively). Pair housing also increased final body weight (BW) compared with individual housing (64.9 ± 0.76 versus 61.7 ± 0.81 kg, respectively). During observation periods, calves housed individually spent more time engaging in nonnutritive sucking than calves housed in pairs (21.5 versus 8.15%). Calves housed in pairs were observed cross-sucking 13.2% of the time during observational periods. In conclusion, although housing Jersey calves in pairs may increase measures of performance, future research should aim to reduce cross-sucking behavior within the Jersey breed through alternative feeding systems or environmental enrichment.

**Key words:** dairy calf welfare, Jersey calf, housing method, calf behavior, calf performance

# INTRODUCTION

Modern dairying is often criticized for the early separation (< 24 h after birth) of the calf from the dam and for individually housing (as opposed to paired or in groups) pre-weaned heifer calves (Rushen et al., 2010). In a recent survey (USDA, 2012), 78.9% of respondents reported that they housed pre-weaned heifer calves individually, either outside (42.1%) or inside heated (10.5%) or non-heated (26.3%) barns. This is in contrast to 15.9% of survey respondents that reported housing pre-weaned animals in any kind of group facilities. While common, individual housing may be a disturbance to some people who may disagree with the restricted space and social isolation from other animals with this type of housing (Rollin, 1996).

The majority of the dairy industry traditionally favored housing pre-weaned calves individually in order to better manage the transmission of disease-causing organisms (Gulliksen et al., 2009). However, recent experiments conducted to evaluate the relative health of calves housed individually versus in groups have produced conflicting results (Kung et al., 1997; Chua et al., 2002). For example, Chua et al. (2002) examined the health of pre-weaned heifer calves housed individually or in pairs and reported that both individual and pair-housed calves remained healthy, and there were no differences observed between housing treatments on the incidence of diarrhea. Similarly, Kung et al. (1997) reported fewer days of medication were provided to calves housed in small groups compared with those housed individually in hutches, challenging the traditional claim of improved calf health in individual housing systems.

Individual housing systems prevent calves from making physical contact with conspecifics. This form of housing may impede social development, as calves may be more fearful of conspecifics and respond by behaving either more or insufficiently aggressive after grouping (Bøe and Færevik, 2003; Rushen et al., 2010). Because of the natural complex hierarchies established by dairy cattle, it is important for calves to learn how to interact socially with conspecifics (Jensen et al., 1999). In addition, Gaillard et al. (2014) recently reported that individual rearing (as opposed to group rearing) may result in cognitive impairments in young dairy calves. The researchers assessed cognitive performance by conducting a reversal learning task; calves were trained to associate a white or black colored stimulus with a food reward, and once calves reached the appropriate learning criterion, the colors were reversed, i.e. calves that were initially trained to associate the white stimuli with the reward then had the reward paired with the black stimulus and vice versa. Pair-housed calves were better able to adapt and modify their behavior after the stimuli were reversed, yet individually housed calves continued to choose the incorrect stimuli. Calves that are group-housed prior to weaning are also better able to learn how to use automated feeding equipment after weaning, as they visit the feeder more often and ingest more concentrate than calves that were previously housed individually (de Paula Vieira et al., 2010). Thus, individual rearing during the pre-weaning period may reduce behavioral flexibility and limit the calves' ability to cope with novel situations or changes within their environment later in life.

In contrast, social interactions may often be coupled with the expression of undesirable behaviors, such as cross-sucking, and this is a prime concern for dairy producers. Cross-sucking is defined as an abnormal behavior wherein non-nutritive sucking directed toward another calf's ears, mouth, navel, scrotum, prepuce, or other body parts occurs (de Wilt, 1985), and this behavior stems from redirection of the calf's innate desire to suckle (Jensen, 2003). One reason dairy producers are reluctant to adopt modern group-housing systems is because this behavior may cause hair loss, inflammation, or infection of the body part exposed to cross-sucking (Lidfors, 1993).

The vast majority of the literature with regard to the behavior and performance of dairy heifer calves housed in groups is breed-specific. Nearly all studies to date have been conducted with Holstein calves, and it is currently unknown if Jersey calves will behave the same as Holstein calves when pair-housed. The duration and/or frequency of cross-sucking behavior also have yet to be quantified for Jersey calves. As there are behavioral differences among breeds of other species, such as aggression in pigs, (Breurer et al., 2003), it may be inappropriate to make the assumption that breeds of dairy calves behave in the same manner when housed similarly. It is possible that cross-sucking behavior may be heightened within the Jersey breed, as Jersey cows are frequently observed performing oral stereotypic behaviors, such as tongue-rolling and intersucking, more often than other breeds (Lidfors and Isberg, 2003).

The overall objective of this experiment was to compare the behavior and performance of Jersey heifer calves housed individually or in pairs. We hypothesized that cross-sucking behavior would occur in pair-housed calves, as all calves were fed milk via bucket, but did not expect this behavior to be detrimental to calf health or performance. Because of social facilitation, we also predicted that pair-housed calves would have increased measures of performance compared with individually housed calves. Lastly, we predicted that the provision of a social partner would increase the temperature within the calf hutch, thus reducing the calves' susceptibility to cold stress during cool weather.

## MATERIALS AND METHODS

This study was conducted at The Ohio State University's Waterman Dairy Center, located in Columbus, Ohio, in accordance with guidelines set by the Institutional Animal Care and Use Committee (Protocol No. 2012A00000099). Forty female Jersey calves born between

August 2012 and February 2013 were blocked by date of birth and allocated to individual or pair housing treatments at birth and monitored for 9 wk (63 d). Calves assigned to the pair housing treatment were also balanced by weight. Calves were housed in hutches (non-tethered, wire pen enclosure) and both individually (n = 20 calves) and pair-housed (n = 20 calves) calves were provided with one hutch placed on loose gravel. Only one hutch was provided to pair-housed calves due to the calves' tendency to remain in the same hutch over 80% of the time when 2 hutches are provided (J. Pempek, unpublished data). The size of the wire pen enclosure for pair-housed calves measured 1.22 m × 2.39 m (1.46 $m^2$/calf) and 1.22 m × 1.17 m (1.43 $m^2$/calf) for individually housed calves. Hutches were bedded with straw.

All calves received 1.9 L of maternal colostrum via bottle from Johne's disease-negative dams as soon as possible after birth and again within 12 h of the first colostrum feeding per regular herd standard operating procedure. If good-quality maternal colostrum was not readily available for use, replacement colostrum (bovine IgG, colostrum replacement; Land O'Lakes Animal Milk Products, St. Paul, MN) was fed to the calf.

***Total serum protein***

Blood samples were collected in 5-mL Vacutainer serum collection tubes (BD Vacutainer Plus Blood Clot Collection Tubes, Franklin Lakes, NJ) via jugular venipuncture within 48 h after the calves were fed colostrum. The blood samples were immediately placed on ice after collection and transported to the laboratory within 1 h. Samples were then allowed to clot at room temperature, after which they were centrifuged at 3,500 RPM (1,180 x *g*) a 4°C for 15 min. Total serum protein was analyzed using a JorVet clinical hand-held refractometer (Jorgesen Laboratories, Inc., Loveland, CO).

### *Feed*

Calves were fed milk replacer (Cow's Match Jersey Blend; 28% crude protein (**CP**) and 25% fat, as-fed basis; Land O' Lakes Animal Milk Products, Shoreview, MN) twice daily at approximately 0600 and 1700 h. Throughout the experiment, milk replacer was provided in buckets. The buckets were removed as soon as the calves completed their milk meal, and it was ensured that calves housed in pairs had access to the milk simultaneously. During the first week of life, calves received 1.9 L of milk per feeding and were then increased to 2.27 L of milk per feeding until the commencement of weaning. Gradual weaning began on d 49, as calves were decreased to one milk feeding (morning only) per day, and all calves were weaned on d 56. Calves had ad libitum access to a texturized starter grain (22% CP; AMPLI-Calf 22 Jersey R40, Land O'Lakes Purina Feed, LLC, Shoreview, MN) medicated with 44 g/t of monensin (Rumensin; Elanco Animal Health, Greenfield, IN) and water throughout the experiment.

### *Behavior Observations*

Calf behavior was recorded by direct observation using instantaneous scan-sampling with 60 s intervals. Observation periods were conducted twice per week (1 h session duration) and were centered around one morning and one evening milk-feeding period. Scan-sampling began 30 min prior to the delivery of milk and ended 30 min after milk delivery to calves. The scan sample period length for each animal was approximately 5 s, and only the initial posture (standing or lying) and behavioral state (non-nutritive sucking, locomotor play, object play, self-grooming, ingesting starter, water or milk, cross-sucking, allogrooming, social play, or other) of the calf was recorded. The recorded behaviors are listed and defined in Table 1.

***Performance and Health***

All calves were weighed at birth and weekly thereafter. Grain consumption was recorded daily by the collection of feed refusals prior to the evening milk feeding. Feed refusals for pair-housed calves were averaged, as it was not possible to monitor individual feed intake. In addition, hip height **(HH)** and wither height **(WH)** and body length measurements were taken at birth and 3, 6, and 9 wk of age.

Fecal scores (Diaz et al., 2001) and rectal body temperature were recorded daily at 1500 h each day. When calves were diagnosed as ill, they were treated per veterinarian recommendations using an oral electrolyte solution (Entrolyte H.E.; Pfizer Animal Health, New York, NY) and antibiotics. Both type and duration of treatment were recorded.

To examine the accuracy of a wireless data logger as a noninvasive alternative to monitoring core body temperature, wireless data loggers (Thermochron iButton DS1922T, Maxim Integrated, San Jose, CA) were adhered to the underside of calves' tails with medical tape and further secured with vet wrap (n = 8 calves due to the cost of data loggers). Each iButton was set to record the calf's temperature once every 15 min in order to observe daily temperature variation throughout the experiment.

***Environmental factors***

AcuRite Wireless Digital Thermometers (Lake Geneva, Wisconsin) were secured within suet wire baskets (KAYTEE Cake Feeder Station, Chilton,WI) for protection and mounted directly above the straw bedding in the back of each hutch in order to monitor daily interior hutch temperature (maximum and minimum). In addition, weather data were collected from the National Oceanic and Atmospheric Administration's National Weather Service (Columbus, Ohio) for all days of the experimental period.

***Statistical analysis***

Data were analyzed as a randomized complete block design with repeated measures in time using the MIXED procedure of SAS (Version 9.3, SAS Institute Inc., Cary, NC). One pair was separated after wk 3 of the experiment due to an aural hematoma; these data were still included as a pair for the analysis with missing data points after wk 3. The covariance structures of error were selected based on the lowest Bayesian information criteria (BIC). Least squares means and standard errors were determined using the LSMEANS statement in the MIXED procedure. Significant differences were declared at $P \leq 0.05$ and a trend at $P \leq 0.10$.

***Behavior analysis***. Because the effect of treatment did not vary across experimental weeks, these data were combined to provide one morning and one evening behavior observation period per calf. The model included the fixed effects of treatment (1 df), observation period (1 df), treatment x observation period interaction (1 df), and the random effect of block (9 df). Calf within treatment by block was used as the experimental unit. To obtain normality, the mean proportion of the behaviors displayed by all calves, independent of housing treatment, was transformed using the arcsin transformation (Snedecor and Cochran, 1967), and all transformed data were back-transformed for reporting. The selected covariance structure of error was the banded main diagonal (UN(1)) structure.

***Performance analysis.*** The model included the fixed effects of treatment (1 df), week of experiment (8 df), treatment x week interaction (8 df), and the random effect of block (9 df). Calf within treatment by block was used as the experimental unit. Birth measurements were used for covariate adjustment of data. The selected covariance structure of error was the first-order autoregressive (AR(1)) structure. Due to the low level of occurrence, morbidity data were summarized descriptively.

***Environmental factors analysis.*** The effects of housing treatment on average internal hutch temperature (below 10ºC) and d below 10ºC were also compared. The model included the fixed effects of treatment (1 df) and the random effect of block (9 df).

## RESULTS

***Behavior***

Behavior results revealed that the posture of calves housed in pairs was similar to the posture of calves housed individually (Table 2). During periods of observation, calves housed individually spent more time engaged in non-nutritive sucking compared with calves housed in pairs (21.5 ± 0.03% versus 8.15 ± 0.03% of total observations). However, calves housed in pairs were observed cross-sucking, which occurred predominantly after the completion of their milk meal. Locomotor play, object play, and self-grooming behaviors were observed less frequently, yet calves housed individually were observed performing object play and self-grooming behaviors more often than calves housed in pairs (Table 2). In addition, calves housed in pairs consumed their milk meal faster than calves housed individually (4.20 ± 0.002% versus 4.86 ± 0.002% of total observations). However, no differences were observed between the amount of time calves spent consuming calf-starter and water (Table 2). Lastly, affiliative behaviors, such as allogrooming and social play, were rarely observed among calves housed in pairs during periods of observation (0.30 ± 0.010% and 0.06 ± 0.003% of total observations, respectively).

***Performance and Health***

Although housing Jersey heifer calves in pairs did not significantly increase overall mean body weight (**BW**) (Table 3), a treatment by time interaction ($P = 0.05$) revealed that calves housed in pairs tended to weigh more than individually housed calves during wk 7 and 8 (Figure

1), and calves housed in pairs completed the experiment with a greater final BW compared with calves housed individually (64.9 ± 0.76 versus 61.7 ± 0.81 kg). In addition, ADG tended to be higher for pair-housed calves compared with calves housed individually (Table 3). Overall grain DMI did not differ between treatments, yet a treatment by time interaction (Figure 2) revealed that calves housed in pairs consumed significantly more calf-starter during wk 9 than calves housed individually (2.36 ± 0.06 versus 2.12 ± 0.06 kg/d).

Calves housed in pairs were taller at the withers compared with calves housed individually (74.7 versus 74.1 ± 0.23 cm). However, the hip heights of calves were similar between both treatments (Table 3). Body length measurements also did not differ among treatments, yet there was approaching tendency for pair-housed calves to grow more from the withers to the pins than individually housed calves (56.1 versus 55.2 ± 0.37; $P = 0.11$).

All calves had a total serum protein concentration > 5.5 g/dl, which did not differ by treatment (Table 4). Calf fecal scores were not affected by housing treatment had no effect on fecal score (Table 4). However, there was a significant week effect, as fecal score increased with age from 1.33 ± 0.12 during wk 1 to 2.98 ± 0.12 during wk 9. Rectal body temperature also did not differ by treatment (Table 4), yet there was a significant wk effect; calves' rectal body temperature decreased slightly with age. All calves remained healthy throughout the duration of the experiment.

Rectal temperature (°C) was best predicted as 37.6 ± 0.75 + 0.03 ± 0.02 * Thermochron iButton temperature (°C). This equation had an $R^2$ value of 0.01 and RMSE of 0.37, indicating that tail skin temperature is not an accurate predictor of calf core body temperature ($P = 0.10$).

### *Environmental factors*

The mean ambient high and low temperatures throughout the duration of the experiment are listed in Table 5; average high temperatures ranged from 3.53 to 30.4°C, and the average low temperatures ranged from -4.48 to 16.35°C. When the internal hutch temperature fell blow 10°C, the average environmental temperature did not differ by housing treatment; calves housed in pairs and calves housed individually experienced similar thermal conditions when the temperature fell below the thermoneutral zone ($3.58 \pm 1.80$ versus $3.59 \pm 1.80$°C). In addition, the average number of days in which calves may have been exposed to cold-stress conditions did not differ by housing treatment; calves housed in pairs experienced approximately $39.4 \pm 2.97$ d below thermoneutral temperatures, whereas calves housed individually experienced $41.0 \pm 2.97$ d below thermoneutral temperatures.

## DISCUSSION

### *Behavior*

Calves housed individually were observed to engage in non-nutritive sucking significantly more often than calves housed in pairs. Under modern production systems and despite having received adequate nutrition, young calves may develop oral stereotypes as they continue to suck on fixtures within the pen, along with other calves if they are housed with conspecifics (de Passillé, 2001). Non-nutritive sucking may be observed under natural conditions, yet it more commonly occurs within artificial rearing systems, and it is directed towards various fixtures of the pen, a dry artificial teat, or if accessible, another calf without receiving any nutritive reinforcement (Jensen, 2003). Previous research suggests that non-nutritive sucking may be detrimental to calf health and performance, as the consumption of nonfeed particles (soil, metal oxides, etc.) can have a direct effect on stomach upset and possibly lead to other health complications (Broom, 1991).

It is important to note that milk was provided only via bucket in this study, which may have contributed to the expression of non-nutritive sucking. Currently, however, this feeding method is widely used for its convenience in the dairy industry. For instance, a study conducted in Canada recently reported that 92.0% of feeding management systems employed the use of an open bucket or pail for milk delivery, whereas only 17.7% of systems employed the use of a bottle fitted with a teat (Vasseur et al., 2009). The young calf's motivation to suckle is inherently strong (de Passillé, 2001), and the inability to perform such behaviors that are intrinsic in nature may directly and indirectly affect animal welfare. A further consequence of the inability to suckle may be the development of stereotypical oral behaviors (Bergeron et al., 2006).

In contrast to individually housed calves, calves housed in pairs engaged in cross-sucking behavior, which was predominantly directed toward the navel and the ears of the companion calf. As mentioned previously, one pair had to be permanently separated as a consequence of this behavior, and unforeseen occurrences of frostbite throughout the winter months, inflammation of navels, and one ear infection (*Mycoplasma bovis*) were also observed. In contrast, few studies conducted with Holstein calves have reported cross-sucking as being injurious to calf health (deWilt, 1985; Chua et al., 2002; Babu et al., 2004). However, the experiments that found this to be a concern only offered milk to calves in a bucket or trough (Margerison et al., 2003), similar to the feeding management system employed in this research study. To reduce the potential detrimental effects of cross-sucking behavior, it is recommended that calves be offered milk via bottle fitted with a teat if they are housed in a group setting.

It is difficult to directly and quantitatively compare the occurrence of cross-sucking behavior across studies, and thus across different breeds, as behavioral observations are typically conducted differently. Future experiments should aim to reduce cross-sucking behavior specifically within the Jersey breed through alternative milk-feeding systems and the use of environmental enrichment devices. In addition, it may be of interest to investigate a potential association between cross-sucking behavior and the stereotypic tongue-rolling behavior, as Jersey cattle predominantly exhibit this oral stereotypic behavior.

***Performance and Health***

In the current experiment, disease prevalence, other than diarrhea, was minimal and did not differ between housing treatments. Calves remained healthy and continued to gain weight rapidly. Calves in our study grew at comparable rates to Jersey calves in other studies, as well; Jensen (2006) reported an ADG of 0.594 kg/d. Housing Jersey heifer calves in pairs improved measures of performance, as was initially hypothesized. ADG tended to be higher for calves housed in pairs compared with calves housed individually, and treatment by time interaction trends revealed that calves housed in pairs consumed more calf-starter during the wk after weaning. Also, calves housed in pairs tended to have a higher BW during the weaning period, which significantly increased during the wk after weaning. Our results agree with previous studies that also have reported increased weight gains for group-housed calves (Xiccato et al., 2001; Chua et al., 2002). Such improvements may be attributed to social facilitation, as group activity and early social interactions allow calves to learn at a faster pace than those reared individually (Babu et al., 2004; Gailliard et al., 2014).

In addition, the weaning period is one of the most stressful periods in the young calves' life (Weary et al., 2008). Thus, social companionship may reduce the level of stress calves experience during this period and also minimize the often-observed slowed growth via social buffering (de Paula Vieira et al., 2010). For instance, de Paula Vieira et al. (2010) reported that pair-housed calves spent more time at the feeder, visited the feeder more often, and ingested more concentrate. The authors also reported that pair-housed calves showed a reduced vocal response to weaning compared with individually housed calves. Although the calves' behavioral response to weaning was not quantified in the present study, calves housed individually did experience a period of growth check. Thus, this research supports the aforementioned studies conducted with Holstein heifer calves and suggests that housing Jersey calves in pairs also mitigates the stressors associated weaning as young calves transition from milk to a solid diet.

***Environmental factors***

The thermoneutral zone for young dairy calves is between 10 to 20°C (Scibilia et al., 1987), and when environmental temperatures drop below this threshold, calves must consume more nutrients for body maintenance (NRC, 2001). Environmental temperature below this range is considered one of the most commonly experienced stressors (Litherland et al., 2014). It was expected that when the internal hutch temperature fell below 10°C, the lower range of the young calf's thermoneutral zone, the average temperature for calves housed in pairs would be higher than the temperature for calves housed individually. However, this initial hypothesis was incorrect, as our results indicated that the temperature within the hutch remained the same independent of treatment during potential periods of cold stress. In addition, although there was no difference observed by treatment, calves experienced chilling or cold-stress over two-thirds of the experimental duration. This is an important management consideration, as the majority of Jersey heifer calves in this experiment experienced cold-stress.

## CONCLUSIONS

Housing Jersey heifer calves in pairs or in small groups allows for early social interactions and may increase measures of performance pre- and post-weaning. Future research should aim to compare Holstein and Jersey breeds behaviorally and reduce cross-sucking behavior specifically within the Jersey breed by using alternative feeding systems or environmental enrichment. In addition, a noninvasive proxy for core body temperature in pre-weaned calves is still needed, as tail skin temperature is not a viable alternative.

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488 **Table 1.** Ethogram of the recorded behaviors and their description

| Behavior | Description |
|---|---|
| Lying | The calf is resting on the ground; head may be supported or unsupported by the neck |
| Standing | The calf is standing with all 4 legs on the ground |
| Other | The calf is ruminating, urinating, defecating, or performing another behavior not described |
| Non-nutritive sucking | The calf's tongue is out of its mouth and is in contact with or biting any fixtures of the pen; may include bucket if milk is not available at the time of observation |
| Locomotor play | The calf is engaged in a gallop, leap, buck-low, buck-high, buck-kick, or turn |
| Object play | The calf is standing; butting head against milk or water buckets or hutch in a playful manner |
| Self-grooming | The calf's tongue is out of its mouth and in contact with its own body |
| Ingesting starter | The calf is consuming calf-starter from a bucket |
| Ingesting water | The calf is ingesting water by drinking from a bucket |
| Ingesting milk | The calf is ingesting milk by drinking from a bucket |
| Cross-sucking | Pair-housed calves only - The calf is sucking on the body of another calf; the sucking movements are performed with the body part in the mouth |
| Allogrooming | Pair-housed calves only - The calf's tongue is out of its mouth and in contact with the head, neck, or body of the companion calf |
| Social play | Pair-housed calves only - The calves are standing front-to-front; butting head against head/neck in a playful manner |

**Table 2.** Least squares means (± SEM) percentage of time calves engaged in each of the behaviors measured

| Behavior (%) | Individual | Pair | SEM | *P*-value |
|---|---|---|---|---|
| Lying | 24.7 | 25.6 | 0.03 | NS |
| Standing | 70.5 | 74.2 | 0.10 | NS |
| Idle | 57.1 | 60.7 | 0.03 | NS |
| Other | 0.37 | 0.28 | 0.004 | NS |
| Non-nutritive sucking | 21.5 | 8.15 | 0.03 | < 0.0001 |
| Locomotor play | 1.02 | 0.66 | 0.01 | NS |
| Object play | 1.36 | 0.21 | 0.01 | < 0.0001 |
| Self-grooming | 1.94 | 0.67 | 0.01 | < 0.001 |
| Ingesting starter | 4.14 | 4.63 | 0.01 | NS |
| Ingesting water | 0.76 | 0.55 | 0.003 | NS |
| Ingesting milk | 4.86 | 4.20 | 0.002 | < 0.05 |
| Cross-sucking | -- | 13.5 | 0.02 | -- |
| Allogrooming | -- | 0.30 | 0.010 | -- |
| Social play | -- | 0.06 | 0.003 | -- |

**Table 3.** Least squares means (± SEM) of BW, ADG, grain DMI, withers height, hip height, and body length measurements for calves housed individually (n = 20 calves) or in pairs (n = 20 calves) during the milk feeding and weaning periods

| Variable | Individual | Pair | SEM | *P*-value |
|---|---|---|---|---|
| BW (kg) | 41.3 | 41.9 | 0.53 | 0.39 |
| ADG (kg/d) | 0.59 | 0.63 | 0.02 | 0.09 |
| Grain DMI (kg/d) | 0.68 | 0.72 | 0.05 | 0.44 |
| Withers height (cm) | 74.1 | 74.7 | 0.23 | 0.02 |
| Hip height (cm) | 76.9 | 76.9 | 0.23 | 0.85 |
| Shoulders to pins (cm) | 65.3 | 65.2 | 0.32 | 0.88 |
| Withers to pins (cm) | 55.2 | 56.1 | 0.37 | 0.11 |

**Table 4.** Least squares means of total serum protein within 48 h of birth and average fecal score (4-point scale) and body temperature for calves housed in pairs (n = 20 calves) or individually (n = 20 calves) during the milk feeding and weaning periods

| Variable | Individual | Pair | SEM | *P*-value |
|---|---|---|---|---|
| Total serum protein (g/dL) | 7.22 | 7.02 | 0.21 | 0.35 |
| Fecal score[1] | 1.98 | 2.08 | 0.09 | 0.28 |
| Body temperature (°C) | 38.8 | 38.8 | 0.03 | 0.27 |

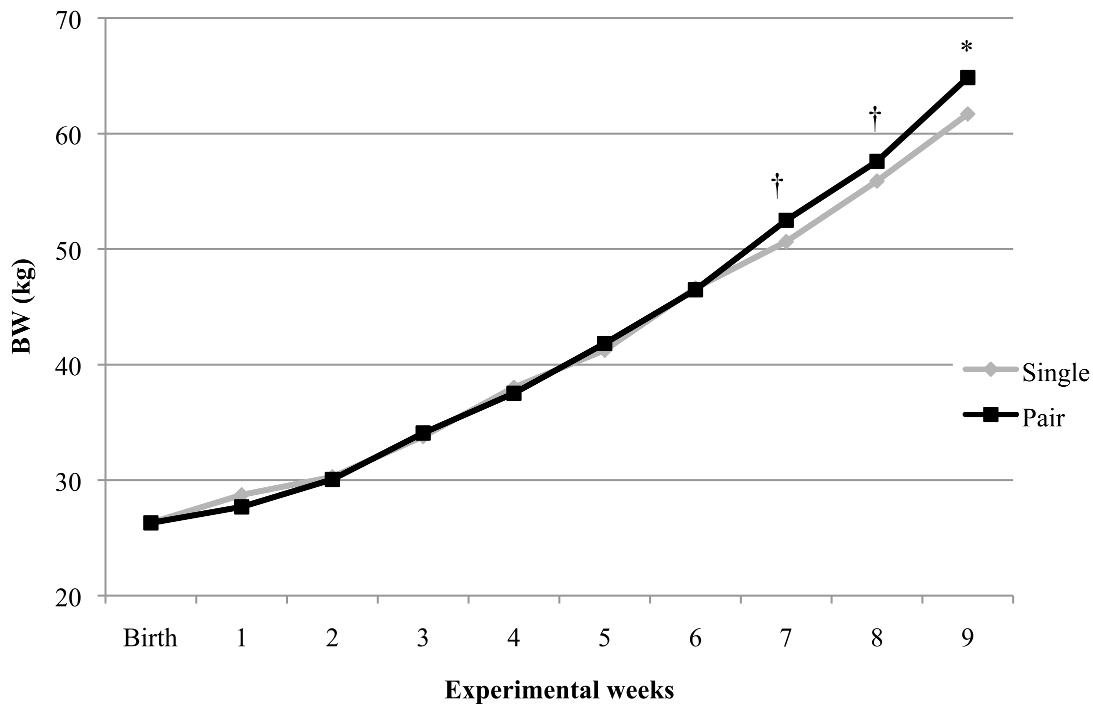
[1]Diaz et al., 2001 (1 = firm, well-formed (not hard); 2 = soft, pudding-like; 3 = runny, pancake batter; 4 = liquid, splatters)

**Table 5.** Mean ambient temperature by month throughout the experimental period

| Month | High Temperature (°C)[1] | Low Temperature (°C)[1] |
|---|---|---|
| August 2012 | 30.4 | 16.4 |
| September 2012 | 24.7 | 12.8 |
| October 2012 | 17.2 | 7.38 |
| November 2012 | 11.0 | 0.24 |
| December 2012 | 7.47 | 0.79 |
| January 2013 | 4.32 | -4.23 |
| February 2013 | 3.53 | -4.48 |
| March 2013 | 7.01 | -1.13 |
| April 2013 | 18.4 | 6.00 |

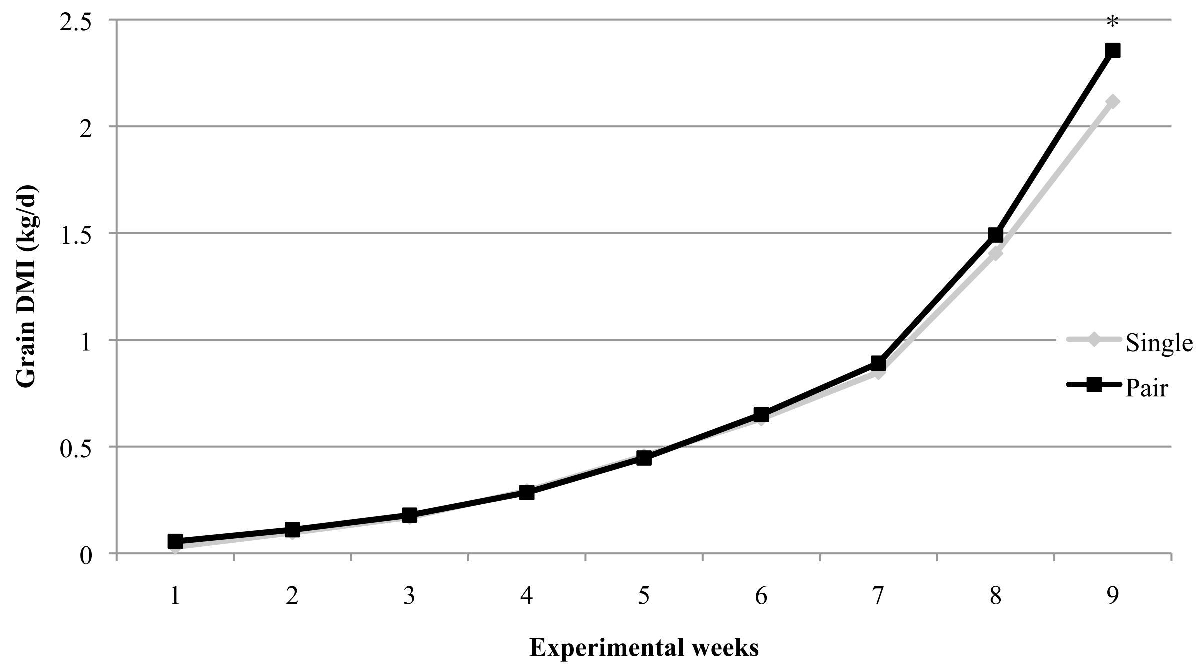
[1]Weighted for the number of calves on trial per month

**Figure 1.** BW for calves housed in pairs or individually during the milk feeding and weaning periods




*Means within week by housing treatment were different ($P$ < 0.05).
†Means within week by housing treatment tended to differ ($P$ < 0.10).

**Figure 2.** Grain DMI for calves housed in pairs (n = 20 calves) or individually (n = 20 calves) during the milk feeding and weaning periods




*Means within week by housing treatment were different ($P < 0.05$).